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Urban Freight Transport Demand Modelling: a State of the Art

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Abstract

The paper provides a review of freight transport demand models for applications in urban and metropolitan areas. The perspective adopted is the short-term one of public decision-makers involved in transport planning and traffic management.

The paper recalls the general methodology to be used for assessing the city logistics scenario and the features of models in relation to the planning horizons: strategic, tactical and operative. The focus is on the transport demand models able to support the assessment of short-term policies/measures. Several models and methods have been proposed. They usually refer to the multi-stage modelling approach and can be classified in terms of reference unit: truck/vehicle, commodity/quantity, delivery and mixed. The paper offers an analysis of pros and cons of each above classes of models. The research prospects are also identified.

Keywords: urban freight, demand modelling, origin-destination matrix, commodity-based models, truck-based models, delivery-based models.

1. Introduction

The current fundamental idea of city logistics is to totally optimize urban logistics activities by also considering the social, environmental, economic, and financial and energy impacts (Taniguchi *et al.*, 2001). A comprehensive collection of results of research projects funded by the European Commission is provided in Delle Site and Salucci (2009), which includes a number of best practices as well as policy implications regarding measures for urban freight distribution. For papers devoted to transport and logistic services with the outline of case studies, refer to Bielli and Filippi (2009) and Taniguchi and Thompson (2010). These studies show that several municipalities have supported the implementation of different measures/policies, but some *ex-post* assessment have often proved their ineffectiveness (Schoemaker, 2006; Dasburg and Schoemaker, 2008; Russo and Comi, 2011a). Many of these measures have been

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implemented without an *ex-ante* assessment supported by simulation models. Simulation models play a key role as they allow us to estimate and evaluate the performances and the impacts generated by measures/policies. In fact, the urban goods movements are the result of a set of choices made by: inhabitants/customers, retailers, wholesalers, carriers and local authorities. Inhabitants/customers decide where to buy, as well as the mode of transport to use, retailers decide the shop location and where to bring the freight sold in the shops, wholesalers, logistics operators and distributors choose their location and how to restock retailers, while carriers decide the delivery process. Finally, city administrations try to govern the overall process aiming to minimize the global cost of the system, made of distribution inner costs, inhabitant transportation costs for shopping, congestion costs and external ones (pollution and road safety). It should be noted that analysis and selection of implementable policies/measures has to consider such actors and find an optimal compromise between all interests of the involved actors (Quak and de Koster, 2008; Stathopoulos *et al.*, 2011; Holguín-Veras and Wang, 2011; Russo and Comi, 2011b).

The Table 1 offers a synthesis of relationships existing among choice dimensions, decision-makers and city logistics policies/measures, and highlights the strict existing relationships with planning horizons:

- *strategic* horizons involve decisions on long-term capital investment programs for the realization of new infrastructures (e.g. urban distribution centres, roads) and/or the change of vehicles and technologies (e.g. environment-friendly vehicles and control systems); these actions could determine modifications both on retail and wholesale activity systems; the model should capture the transport and land-use interactions;

Tab. 1 – Choice dimensions, decision-makers and city logistics policies/measures.

	Planning horizon*	**Demand**			**Supply**			
Choice dimension		*Distribution centre location?*	*Shop location and dimension?*	*Acquisition zone?***	*Service type?***	*What time?***	*Which vehicle?***	*Which restocking tour?***
Decision-maker								
Retailer		x	x	x	x	x	x	x
Wholesaler					x	x	x	x
Carrier						x	x	x
Measures/Policies								
Urban distribution centre/transit point	L/M			x	x	x	x	x
Time windows	S				x	x		x
Weight constraints	S				x		x	x
Emission constraints/ Incentives for LEV	M/S				x		x	
Road/parking pricing	S				x		x	x
Shipment size/load factor	M/S				x		x	
Incentives for 3P	M				x		x	x
ITS	S/M							x

* *L=Long-term (strategic); M=Medium-term (tactical); S=Short-term (operative)*
** *choice dimensions mainly impacted by short-terms policies/measures*

- short/medium term *tactical* implementation is concerned with decisions on projects requiring limited resources, usually assuming minor changes (or none) in infrastructures (e.g. loading and unloading zones, road-pricing); the models should mainly support the design of urban freight transportation system;
- short-term *operative* programs can include the implementation of some measures/policies that regard particular aspects of governance (e.g. time windows); the model should mainly point the simulation of urban freight transportation system.

Then, a general methodology able to simulate the urban freight transport should consist of a set of models as pictured in Figure 1, in order to:

- forecast how the key land-use activities (business and employment, housing and population/households), the use of transport systems, and associated markets may be expected to change over time, taking account of the transport infrastructure and its performance (Land-Use Transport Interaction - LUTI - models);
- forecast the freight quantities requested by end-consumers through the simulation of shopping mobility;
- simulate the distribution process of different involved decision-makers (e.g. retailers, wholesalers, carriers; demand models);
- represent the transportation infrastructures with their operation characteristics (supply models) and how to modify supply in order to optimize given objectives while satisfying given constraints (design/what to models);
- assign the multi-commodity flows to the multimode network (assignment models);
- estimate and evaluate the performances and the impacts of a given city logistics scenario (performance model).

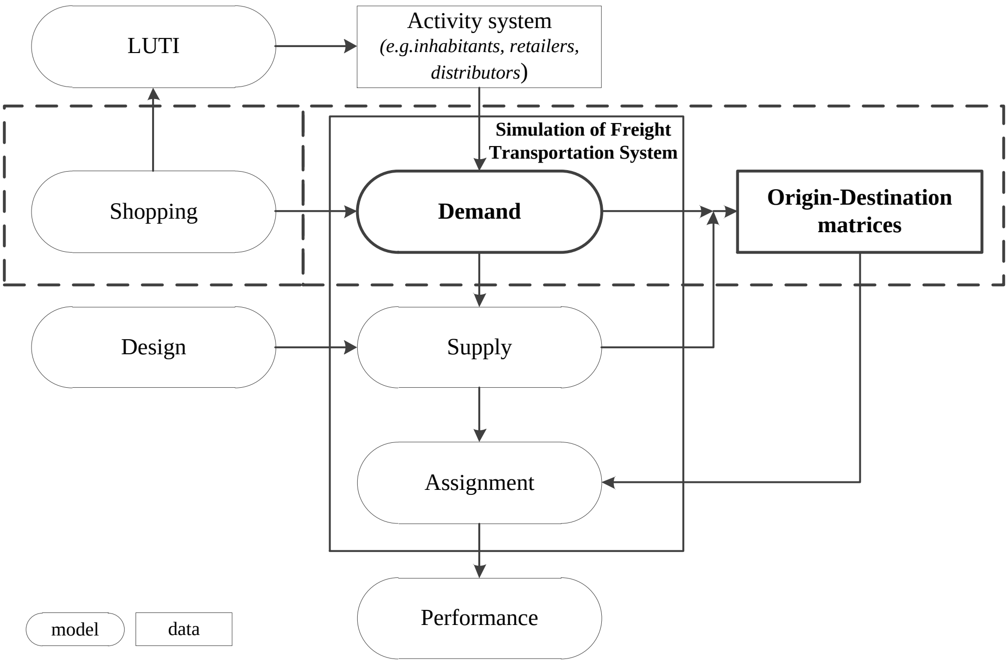

Fig. 1 – Urban freight transport modelling structure.

This described methodology simulates the behaviour of the transportation system and its output forms the basis for the strategic, tactical and operative analysis. These methodologies are quite well known for regional/national planning and only in the recent years the urban and metropolitan freight transport scale has been pointed out (Crainic *et al.*, 2004 and 2009a; Lindholm and Nehrends, 2012).

In this context, the paper focuses on demand models able to support the assessment of short-term policies/measures, in terms of responses of several decision-makers after the implementation of a new city logistics scenario (Tab. 1).

In this perspective, the paper provides a review of the current methods and models for simulating the urban freight transport demand able to support the assessment of short-term city logistics scenarios (section 2), and concludes with considerations on the aptitude of the reviewed models and on the direction of current research (section 3).

2. Urban freight transport demand modelling

The need of finding solutions capable to simulate effects of policies/measures before their implementation, in the framework of an *ex-ante* assessment, is stimulating the investigation of demand models to estimate freight Origin-Destination (O-D) flows. These models belong to two main classes: macro-economic and multi-stage models (Regan and Garrido 2001). The former models (e.g. Input-Output and Spatial Price Equilibrium models) are more suitable for long and medium-term analysis (Abraham and Eng, 1998;, Giuliano *et al.*, 2010). At the other hand, the multi-stage models meet the request of planner for short-term plans. Even though several classifications have been proposed (Ambrosini and Routhier, 2001; Ambrosini *et al.*, 2008; Chow *et al.*, 2010), an extension of that proposed by Ogden (1992) and Taniguchi *et al.* (2001) consists of classifying the multi-stage models in relation to the reference unit of quantity or delivery moved (commodity-based and delivery-based, respectively) or freight vehicle by which transport is made (truck-based) or mixed commodity/delivery-based (Fig. 2).

In the following sub-sections, the four previous classes of models will be reviewed.

3.1 Truck-based models

The reference unit is the trip of freight vehicles (*truck/commercial vehicle*). The base structure provides two steps. The first one allows us to estimate the number of freight vehicles attracted or generated by individual zones. The subsequent step provides the spatial distribution (O-D matrices) of the previous estimated flows. Sometimes, the models are specified and calibrated for different vehicle types (e.g. light goods vehicles, heavy goods vehicles). Ogden (1992) proposed some regressive models for the cities of Chicago, Vancouver and Melbourne. In the city of Chicago, the attracted and generated vehicles, according to the classes of light, medium and heavy, have been estimated as function of variables specific of the commercial activities and have been correlated with passenger trips. In Vancouver and Melbourne, a relationship among vehicles and activities and other socio-economic and accessibility variables has been used. All these models are specific for the area where they have been calibrated and have shown serious shortcomings in the transferability to other urban contexts.

Lawson *et al.* (2012) have analysed the effects of land-use and business size (quantified as number of employees) on freight trip generation, using different statistical inference techniques. The findings of this research are based on a dataset from New York City, specifically Manhattan and Brooklyn. The authors also confirm the difficulty to extend the results of this type of models to other cities.

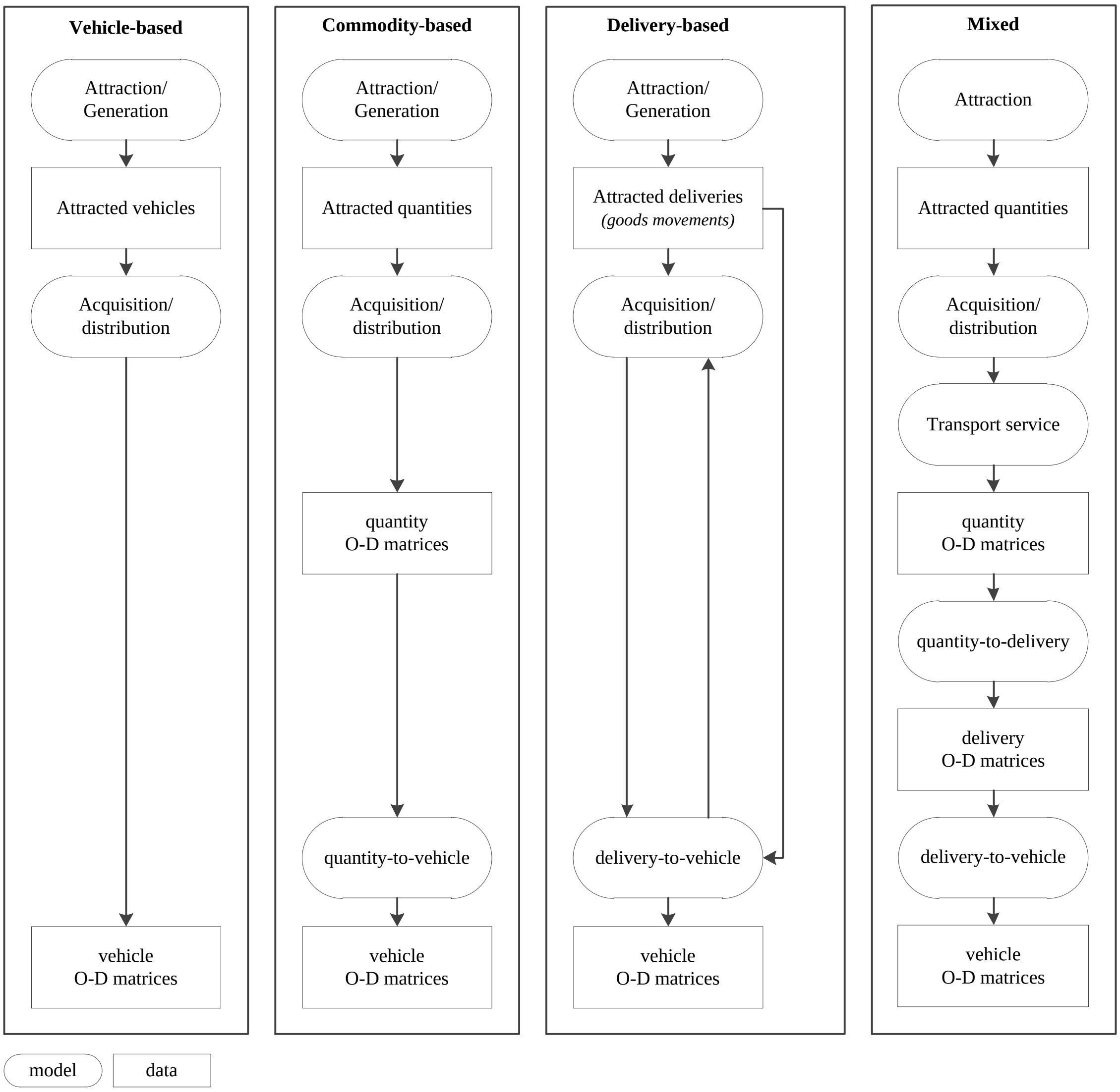

Fig. 2 – Vehicle, commodity and delivery based modelling structure.

The following step concerns the spatial distribution. Gravity type models have been formulated and calibrated where the number of trips between two zones is in direct proportion to the number of trips produced in the origin zone, to the number of trips attracted in the destination zone, and in inverse proportion to the generalised travel cost between origin and destination zones (Spielberg and Smith, 1981). These types of models could well reproduce round trip (one origin – one destination), but fail in the trip chain (tour) simulation. In order to overcome this limit, Wang and Holguin-Veras (2009) have proposed to apply the entropy maximization considering the total number of commercial vehicle trips generated by (vehicle generation) or attracted to (vehicle attraction) each zone, and the total travel cost on the network. Instead Sonntag (1985), Lohse (2004) and Janssen and Vollmer (2005) has developed a procedure that allows to combine the single trip into tours. This method combines the trips to a tour through a so called *savings function* that synthesizes the share (obtained from direct survey) that a trip can be included in a tour. It has been implemented within the WIVER software (Ambrosini *et al*., 2008) and was applied in the many German and European traffic planning processes.

Although truck-based models estimate directly O-D trips of freight vehicles, they are suitable to be used for the simulation of the current scenario, but they can difficultly to be applied in forecasting analysis. Truck-based models have the advantage of the ease of data gathering (e.g. using automatic traffic counts) which facilitates the calibration and validation, but they are not able to account properly for changes in the mechanisms underlying demand generation. Another difficulty of the truck-based models relates to the treatment of scenarios where modes other than road are considered.

2.2 Commodity-based models

Commodity-based models consider as reference unit the quantity of commodity. The estimation of vehicle O-D matrices by commodity-based models is carried out by a sequence of models:

- *attraction model*, which provides the commodity/quantity flows attracted by each zone generally in function of socio-economic data;
- *acquisition model*, which provides the zone from where the commodity/quantity flows are originated and, hence, it allows to determine the quantity O-D flows;
- *quantity-to-vehicle model*, which receives as input the commodity/quantity O-D flows and converts them into vehicles.

Traditionally, the first stage concerns the attraction, instead of generation, because the focus of modelling is usually only on a part of freight flows that leave from a wholesaler area. For example, the catchment area of the wholesalers could include zones that are not consider in the study area.

The attracted quantity of freight is usually expressed as linear function of zonal socio-economic data. For examples, Ogden (1992) proposed to estimate the attracted quantity, according to different freight types (i.e. agriculture and food products, construction materials, manufacturing products, oil products, garbage, other), as function of attributes including: number of clerical workers, number of workers, number of employed in manufacturing activities, population and number of households in each zone. Nuzzolo *et al.* (2009) calibrated some regressive attraction models for the metropolitan area of Rome (Italy). Seven freight types have been considered: foodstuffs, home accessories, stationery, clothing, building materials, household and personal hygiene, and other goods. The daily attracted quantity has been expressed as function of employees in retailing activities and dummy variables introduced in order to measure the different power of selling zones with high shop density.

Allen *et al.* (2008) have suggested to point out that the demand for urban freight transport activity is derived from the demand for goods flows produced or consumed in urban area. In fact, some authors propose to obtain the attracted freight quantity assuming that commodity flows are generated by the consumption of goods, as part of the conduct of a given, generic urban activity undertaken by end-consumers (see Fig. 1;

e.g. purchase/shopping demand - example of a joint/direct model: Oppenheim, 1994; example of a partial share model: Russo and Comi, 2004; Gonzalez-Feliu *et al.*, 2010).

Kawamura and Miodonski (2012) have examined the relationship between consumer freight demand and land use in an empirical manner. Then, tonnage delivered to each Census tract was estimated. Their analysis found that the amount of retail goods delivered per person seems to decrease with household density, which may suggest that living in a compact dwelling unit has an effect of reducing goods consumption.

Once the quantities attracted by each zone are obtained, it is necessary to determine the zone from where the commodity flows are generated by an acquisition model with destination constraint. Few models of this sort have been actually developed at the urban level, probably because of lack of commodity flow data to calibrate the models (Browne *et al.,* 2007; Holguín-Veras and Jaller, 2012). Ogden (1992) proposed gravity type models for the city of Melbourne, while recently some authors have developed random utility acquisition models (e.g. multinomial logit models) formulated as gravity type models. Examples of applications in Italy are in Nuzzolo *et al.* (2006, 2009) where the emission variable is the number of employees in wholesaling activities and the separation variable is the generalised travel cost between the given origin-destination pair. An acquisition model for retailer's standpoint is proposed by Russo *et al.* (2008).

Having identified the freight origin and destination zones, it is necessary to convert O-D flows from quantity to vehicles. This stage is quite complex because we need to consider different factors that can influence the composition of vehicle load: shipment size, transport service type, vehicle type and restocking journey (i.e. round trip or trip-chain/tour).

The shipment size is largely dependent upon the freight type being transported and the dimension of receiver (e.g. shop, supermarket, store). The simplest solution is to consider only round trips and to allocate to each vehicle a quantity equal to the average transported quantity, as proposed by Nortmann (1984). Average values of shipment size for freight type obtained in Italian contexts have been reported by Nuzzolo *et al.* (2006, 2009). The average values of transported quantity have also to take into account the empty trips. Several studies have factored the empty trips, e.g. have considered that they are a fraction of the load trips. A basic method to estimate the amount of empty trips is to apply the vehicle load factor. Hautzinger (1984) focuses on the empty trips of return trips. He models the empty trip as a function of the commodity flow and the commodity flow is then converted into vehicle trips using the load factor. Chin and Hwang (2006) propose a model to estimate the load factor distribution. However, in literature, we find some works which propose to model the flow of empty commercial vehicles as a function of a given matrices of commodity flows (Holguın-Veras and Thorson, 2003; Holguın-Veras and Zorrilla, 2006).

The analysis of quantity O-D matrices can also detailed according to the type of transport service used for restocking the retail activities, that can affect the definition of vehicle load and hence the vehicle journey. Marcucci and Danielis (2008) investigated how transport decisions are made by receivers or by transport operators about the potential use of an urban freight consolidation centre of Fano (Italy). Russo and Comi (2010), within a general modelling framework to simulate the goods movements, point out the retailer's choice for restocking in own account and propose some behavioural models for its simulation.

In literature, there are few models for the simulation of vehicle type choice. For example, Nuzzolo *et al.* (2006, 2010) propose some statistic-descriptive models. The vehicle type is function of freight type and service type (own account, third parties). Russo *et al.* (2008), and Nuzzolo and Comi (2011) propose logit models for simulating the vehicle choice of a retailer that restocks in own account. Wang and Hu (2012) propose some multinomial and nested logit models for the choice of vehicles of businesses and commercial sectors in urban areas, considering five vehicle types and assuming different choice behaviour in relation to round trip or tour.

In order to allocate the freight quantity to each vehicle type (i.e. shipment size), a transported quantity should be associated to each vehicle. This variable depends certainly on the freight type. Average values of transported quantity in function of freight and vehicle types are reported in Nuzzolo *et al.* (2006, 2009) for some Italian towns and large metropolitan areas.

In Wisetjindawat *et al.* (2005), the choices are structured as a two level-nested logit model: carrier choice (between private and business trucks) and vehicle choice (between large and small trucks). The choice decision depends on the characteristics of restockers and customers (such as industry type and number of employees), the attributes of commodities (such as freight type, shipment size and frequency) and so on.

Finally, last step required for converting O-D matrices from quantity to vehicle consists of restocking journey investigation. It should be noted that the vehicle O-D matrices are quite different from quantity O-D matrices as it happens that the same vehicle can move through different destinations along the same tour. Therefore, tour-based approach is developed to replace the traditional trip-based paradigm. Two different approaches have been proposed: disaggregate (e.g. micro-simulation or agent-based) and aggregate ones.

The disaggregate models generally use micro-simulation and optimization models (Friesz *et al.*, 2011) in order to simulate the different strategies for urban distribution done by a representative user belonging to different decision-maker categories. This approach involves the development of tour models. A number of different principles have been used to accomplish this, leading to models based on: logistic considerations (Boerkamps and Binsbergen, 2000; Crainic *et al.*, 2009b; Russo *et al.*, 2010; Bielli *et al.*, 2011), behavioural models (Stefan *et al.*, 2005), activity models (Gliebe *et al.*, 2007), or profit maximization behaviour (Thorson, 2005; Holguin-Veras and Patil, 2005). However, in spite of their significant potentials, the typical implementation of these types of models has a fundamental limitation which is related to the lack of behavioural support to the way in which the individual tours are generated (Wang and Holguin-Veras, 2008). The use of enumeration methods (Cascetta, 2009) can help to overcome this limit. In fact, it is assumed that the whole population can be represented by a random sample of individuals extracted from it.

The aggregate models consider the average behaviour of all restockers (or categories of restockers) starting from the same warehouse zone. For the tour definition, two types of discrete choice models are used to generate the probabilities to choose the next destination stop locations and to make the decision of whether return to the base (warehouse) or not on each tour.

Hunt and Stefan (2007) proposed, within a general modelling system in the city of Calgary (Canada), logit models where the systemic utility of next stop location is function of: number of stops made previously, total time that has been spent up to that point, and accessibility for the current location to all categories of employment in all zones for the vehicle type being used.

Raothanachonkun *et al.* (2007) proposed a procedure where the choice of next destination in a tour is made by utilizing the characteristics of adjacent zones including internal movements, average payload, average unloading and remain freight to be delivered.

Wang and Holguin-Veras (2008) have developed a logit model where the key variables affecting the choice of destination location in a tour can be categorized into two groups: variables associated with an alternative destination such as the distance from the current location, the amount of cargoes, available for picking up/delivering at the destination, and memory variables representing the history of tour (e.g. the cumulative distance covered up to the current location, the cumulative amount of cargoes picked-up/delivered to the current location).

The current commodity-based models have reached a pretty good maturity, but few authors propose a complete modelling framework. The proposed models mainly investigate some specific stages, e.g. attraction and distribution, transport service type.

2.3 Delivery-based models

The delivery approach focuses on movements/deliveries (pick-ups and deliveries); the use of delivery as reference unit allows to have a direct link between generators and transport operators, through the use of the same reference unit. The models proposed within the delivery-based approach consist of a sequence of statistic-descriptive models.

A first example of this class of models has been developed in France. The model, called FRETURB, has been developed by LET (Routhier and Aubert, 1998; Routhier and Toilier, 2007). It consists of three modules which interact with each other: a pick-up and delivery model including flows between all the economic activities of a town; a town management module, consisting of transport of goods and raw material for public and construction works, maintenance of urban networks (sewers, water, phone), and garbage; a purchasing trips model, modelling shopping trips by car, which represents the main last kilometre trips to end-consumers.

The pick-up and delivery (generation and attraction) model is a regression-based model. The weekly average number of goods movements (deliveries and pick-ups) is a function of 45 freight types, type of the activities (store, warehouse, office, headquarter) and number of employees of the establishment. These flows are characterised in terms of transport service, vehicle and journey types, and, finally, are allocated to some identified journeys in order to obtain the vehicle O-D matrices.

The model allows us to estimate traffic volumes in and between each zone, according three types of vehicles and the type of served activity. At moment, the model was included in a software and has been implemented in about 20 French towns (including Paris, Lyon and Lille).

Based on the French approach, CityGoods has been developed by Gentile and Vigo (2006). The prototype model was tested on several cities of Emilia-Romagna Region (Italy). The objective was to build a demand generation model in order to estimate the yearly number of operations generated by each zone. On the basis of surveys among hauliers, shippers, establishments and drivers, they propose a specific approach for the generation of total number of movements as a function of the NACE (European Classification of Economic Activities) code and the number of employees at each establishment. The generation model uses a hierarchical classification of activities of the establishments in a zone.

Muñuzuri *et al.* (2004) proposes a model to estimate O-D matrices in Seville, based on entropy maximisation and Frank-Wolfe's linear approximation to minimize the total direct transport costs, subject to supply and demand constraints. Results have shown significant differences between actual freight vehicle flows and those estimated by the model. Some improvements of this research can be found in Muñuzuri *et al.* (2010).

Even though the delivery reference unit is close to that used by transport and logistics operators, the current delivery-based models are mainly statistic-descriptive and can be able to reproduce the actual scenario. They fail in forecasting analysis in which the effects of city logistics measures/policies should be assessed.

Then, based on the statement that the current literature does not enough investigate the direct relation between policies/measures and models, Nuzzolo *et al.* (2009; 2010) proposed a new modelling system that is useful for assessing the effects due to the implementation of the city logistics policies/measures pointing out on each choice that could be influenced. In particular, according to that the quantity should be used in order to capture the mechanism underlying the generation of freight demand and the delivery to follow the decisional and logistic process of restocking, the authors provide this new modelling framework that includes an intermediate delivery step able to improve the conversion of flows from quantities to vehicles. In fact, goods vehicles are used to carry a wide range of different goods and the use of delivery unit can improve the definition of vehicle load.

The model system consists of different steps aggregated into three model sub-systems that allow us to estimate the:

- average quantity O-D matrices characterised for transport service types (e.g. retailer in own account or by carrier);
- average delivery O-D matrices characterised for transport service types and time slice;
- average vehicle O-D matrices also characterised for departure time, number of stops per journey and vehicle type.

The conversion of O-D matrices from delivery to vehicle is carried out using an aggregate multi-stage restocking tour model that considers the average behaviour of all restockers (or categories of restockers) starting from the same warehouse zone. This phenomenon is modelled through the definition of the trip chain order (that is the number of stops in a tour departing from a given warehouse location zone; Nuzzolo *et al.*, 2012) and the choice of the delivery locations (Nuzzolo *et al.*, 2011). This method allows us to highlight that there are different behaviours depending on the number of stops/deliveries within the tour. This general system of models has been successfully used for the estimation of urban freight flows by road in the initial assessment of future scenarios, as well as to calculate the impacts due to new city logistics policy implementation.

2.4 Mode choice

In order to improve the conditions of pollution and congestion of urban areas, it could be necessary to find modes different than conventional road vehicles. Therefore, mode choice models are of interest in feasibility studies of new transport solutions for urban areas. While the transport of freight within urban and metropolitan areas may be allocated amongst various modes of transport, in practice this stage of modelling is rarely if ever modelled (Regue and Bristow, 2012). In literature, the models developed for this scope refer mainly to intercity transport. Examples of these model types are given by McFadden *et al.*, (1986). Holguín-Veras (2002) and Danielis and Marcucci (2007) and Rich *et al.* (2009).

Nuzzolo *et al.* (2008) present the results of technical and economic feasibility analysis on freight distribution by railway within a metropolitan area. The study area is the Sorrentina Peninsula (one of the most famous tourist area in the middle of Italy, near Naples) which is well-known for its low-accessibility from the freight distribution point of view.

3. Conclusions

Today, most cities have to deal with the large number of vans and trucks delivering goods in the urban area, while preserving the economic sustainability of the businesses located in the city and, at the same time, the environmental quality. Many measures/policies to reduce the negative effects of freight transport have been implemented in cities in Europe and around the world without *ex-ante* assessment and have not always been effective. Simulation models for urban freight transport demand are very important, since estimates of the performances and of the impacts generated by city logistics measures are required for assessing them.

In this paper, the state-of-the-art on urban freight transport demand modelling has been reviewed. Different approaches have been presented, along with their advantages and disadvantages. In particular, the demand models have been classified according to the nature of the reference unit into the four classes: truck, commodity, delivery and mixed.

Truck-based models allow simulation of the current scenarios but are difficult to use for forecasting analysis. They have the advantage of the ease of data gathering (traffic counts with automatic means can also be used) which facilitates the calibration and validation. However, they are not able to account properly for changes in the mechanisms underlying demand.

The commodity-based approach allows simulation of the fundamental mechanisms underlying freight transport demand, but shows two serious shortcomings. The first is that only some specific choice dimensions have been investigated and an overall modelling framework misses. The second is that there is a need to obtain data in terms of quantity freight flows from transport and logistics operators. Even though around the world the practice of assembling freight demand databases by private companies from waybill samples, and of complementing them with small origin-destination surveys, is increasing, this information is hard to get (many producers and distributors are reluctant to release information which may affect their business, such as customers and quantities) and need high costs.

The delivery-based models are more interesting because they use the same reference unit of transport and logistics operators, but only statistic-descriptive models have been developed. At the current status, they are difficulty suitable for forecasting analysis. The above limit with respect to obtain data from transport and logistics operators in terms of deliveries also exists.

The mixed quantity-delivery models should seem much interesting. They allow to combine the three previous reference units and to create a direct link between the interacting behaviours of commodity consumers and commodity suppliers/shippers/retailers, and between policies/measures and stakeholders' behaviour. Then, it could become an useful tool for *ex-ante* assessment of city logistics scenario.

We can conclude that, although the progress, it is still necessary that the models are mainly addressed to policy maker needs in order to well estimate the impacts due to the implementation of new city logistics policies/measures. In fact, in the current urban freight demand modelling literature, the direct relation between policies/measures and stakeholders' behaviours is not enough investigated.

The research should be also addressed to develop a general modelling framework in order to simulate goods movements at urban scale combining passenger shop travelling and commodity flows and taking into account the mechanism of the localization of freight centres/platforms and shopping centres. The above goals could include the study of the dynamic evolution of interactions for both short and long term effects: the short term effects consider the behavioural purchase process of customers, and the urban freight transport and logistics in order to define a complete modelling architecture . The long term effects can be taken into account transport/land-use interactions trough LUTI-type modelling, mainly developing models of localization of urban distribution centres and large shopping centres.

Finally, the transferability of the models should be pointed out.

References

Abraham, J. E. and Eng, P. (1998) *A review of the MEPLAN modelling framework from a perspective of urban economics*. University of Calgary, Department of Civil Engineering Research Report No. CE98-2.

Allen, J., Browne, M., Cherrett, T. and McLeod, F. (2008) *Review of UK Urban Freight Studies*. Report produced as part of the Green Logistics Project: Work Module 9 (Urban Freight Transport), London, U.K., http://www.greenlogistics.org.

Ambrosini, C. and Routhier, J. (2001) "Objectives, methods and results of surveys carried out in the field of urban freight transport: an international comparison". In: *Proceedings of the 9th World Conference on Transport Research*, Seoul, South Korea.

Ambrosini, C., Meimbresse, B., Routhier, J., Sonntag, H. (2008) "Urban freight policy-oriented modelling in Europe". In: *Innovations in City Logistics* (E. Taniguchi and R. G. Thompson, eds.), Nova Science Publishers, Hauppauge NY, 197-212.

Bielli M. and Filippi F. (eds) (2009) "Special Issue on Methods, Tools and Applications in Transport and Logistic Services". In: *International Journal of Services Sciences, 3/4*.

Bielli, M., Bielli, A. and Rossi, R. (2011) "Trends in models and algorithms for fleet management". In*: Procedia Social and Behavioral Sciences 20*, Elsevier, 4-18.

Boerkamps, J.H.K., van Binsbergen, A.J., Bovy, P.H.L. (2000) "Modeling behavioral aspects of urban freight movement in supply chains". In: *Transportation Research Record 1725*, 17–25.

Browne, M., Allen, J., Woodburn, A., Patier, D. and Routhier J.L. (2007) "Comparison of urban freight data collection in European countries". In: *Proceedings of the 11th World Conference on Transport Research*, Berkeley CA.

Cascetta, E. (2009) *Transportation Systems Engineering: Model and Application*. Springer.

Chin, S., and H. Hwang (2006) "Converting freight flow information to truck volumes". In: *Proceedings of the 85th Transportation Research Board Annual Meeting*, Washington DC.

Chow, J. Y. J., Yang, C. H. and Regan, A. C. (2010) "State-of-the art of freight forecast modeling: lessons learned and the road ahead". In: *Transportation 37(6)*, Springer Science+Business Media, LLC, 1011–1030.

Crainic, T. G., Ricciardi, N. and Storchi, G. (2004) "Advanced freight transportation systems for congested urban areas". In: *Transportation Research Part C 12 (2)*, Elsevier, 119–137.

Crainic, T. G., Ricciardi, N. and Storchi, G. (2009a) "Intelligent freight-transportation systems: Assessment and the contribution of operations research". In: *Transportation Research C (17)*, Elsevier, 541 – 557.

Crainic, T. G., Ricciardi, N. and Storchi, G. (2009b) "Models for Evaluating and Planning City Logistics Systems". In: *Transportation Science 43 (4)*, Informs, 432-454.

Danielis, R. and Marcucci, E. (2007). Attribute cut-offs in freight service selection. In: *Transportation Research Part E 43*, Elsevier, 506–515.

Dasburg, N. and Schoemaker, J. (2008) *Quantification of Urban Freight Transport Effects II*. BESTUFS Consortium, www.bestufs.net.

Delle Site P. and Salucci M.V. (2009) *Freight Transport. Thematic Research Summary*. TRKC (Transport Research Knowledge Centre) Project, Sixth Framework Programme, European Commission. http://www.transport-research.info/

Friesz, T. L., Lee, I and Lin C.C. (2011). Competition and disruption in a dynamic urban supply chain. In: *Transportation Research Part B 45*, Elsevier, 1212–1231.

Gentile, G. and Vigo, D. (2006) "A Demand Model for Freight Movements Based on a Tree Classification of the Economic Activities Applied to City Logistic CityGood". In: *Presentation in the 2nd roundtable*, BESTUFS workshop TFH, Wildau.

Giuliano, G., Gordon, P., Pan, Q., Park, J. Y. and Wang L. (2010). Estimating Freight Flows for Metropolitan Area Highway Networks Using Secondary Data Sources. In: *Networks and Spatial Economics (10)*, Springer Science + Business Media, LLC, 73–91.

Gliebe, J., O. Cohen and J.D. Hunt (2007) "A Dynamic Choice Model of Urban Commercial Vehicle and Person Activity Patterns". In: *Proceedings of the 86th Transportation Research Board Annual Meeting*, Washington DC, USA.

Gonzalez-Feliu, J., Toilier, F. and Routhier, J.L. (2010) "End-consumer goods movement generation in French medium urban areas". In: *Procedia - Social and Behavioral Sciences 2 (3)*, E. Taniguchi and R. G. Thompson (eds.), Elsevier Ltd, 6189-6204.

Hautzinger, H. (1984) "The Prediction of Interregional Commodity Vehicle Flows: Some New Modeling Concepts". In: *Proceedings of the 9th International Symposium on Transportation and Traffic Theory*, VNU Science Press.

Holguín-Veras, J. (2002) "Revealed Preference Analysis of the Commercial Vehicle Choice Process". In: *Journal of Transportation Engineering 128 (4)*, American Society of Civil Engineers, U.S.A., 336-346.

Holguín-Veras, J. and Jaller, M. (2012) “Comprehensive freight demand data collection framework for large urban areas” In: *Proceedings of 91st Annual Meeting of Transportation Research Board (TRB)*, Washington D.C., U.S.A..

Holguin-Veras, J. and Patil, G. R. (2005) “Observed trip chain behaviour of commercial vehicles”. In: *Transportation Research Record 1906*, ASCE, USA, 74-80.

Holguín-Veras, J. and Thorson, E. (2003) “Modeling commercial vehicle empty trips with a first order trip chain model”. In: *Transportation Research Part B 37*, Elsevier Ltd, 129-148.

Holguín-Veras, J. and Wang, Q. (2011) “Behavioral investigation on the factors that determine adoption of an electronic toll collection system: Freight carriers”. In: *Transportation Research Part C 19 (4)*, Elsevier Ltd, 593-605.

Holguín-Veras, J. and Zorrilla, J. C. (2006) “A first approximation to longitudinal modeling of commercial vehicle empty trips”. In: *Proceedings of Annual Meeting of Transportation Research Board,* Washington D.C., U.S.A..

Hunt, J. D. and Stefan, K. J. (2007) “Tour-based microsimulation of urban commercial movements”. In: *Transportation Research Part B 41(9)*, 61-71.

Janssen, T. , Vollmer, R. (2005) “Development of a urban commercial transport model for smaller areas”. *German Society for Geography*, Annual meeting 2005, Berlin.

Kawamura, K. and Miodonski, D. (2012) “Examination of the Relationship between Built Environment Characteristics and Retail Freight Delivery”. In: *Proceedings of 91st Annual Meeting of Transportation Research Board (TRB)*, Washington D.C., U.S.A..

Lawson, C. T., Houlguin-Veras, J., Jaller, M. ,Campbell, S. and Powers, E. L. (2012) “Estimation of freight trip generation based on land-use”. In: *Proceedings of 91st Annual Meeting of Transportation Research Board (TRB)*, Washington D.C., U.S.A..

Lindholm, M. and Nehrends, S. (2012) “Challenges in urban freight transport planning – a review in the Baltic Sea Region”. In: *Journal of Transport Geography 22*, 129-136.

Lohse, D. (2004) *Travel Demand Modelling with Model EVA - Simultaneous Model for Trip Generation, Trip Distribution and Mode Choice*. TU Dresden, Working paper.

Marcucci, E. and Danielis, R. (2008) “The potential demand for a urban freight consolidation centre”. In: *Transportation 35*, Springer Science+Business Media, LLC. 269-284.

McFadden, D., Winston C. and Boersch-Supan, A. (1986) “Joint estimation of freight transportation decisions under non-random sampling”. In: *Analytical Studies in Transport Economics* (A. Daugherty, ed), Cambridge University Press, 137-157.

Muñuzuri, J., Cortés, P., Onieva, L. and Guadix, J. (2010) “Modelling peak-hour urban freight movements with limited data availability”. In: *Computers & Industrial Engineering 59*, Elsevier Ltd, 34–44.

Munuzuri, J., Larraneta, J., Onieva, L. and Cortes, P. (2004) “Estimation of an origin-destination matrix for urban freight transport. Application to the city of Seville”. In: *Logistics Systems for Sustainable Cities - Proceedings of 3rd Conference on City Logistics* (E. Taniguchi and R. G. Thompson, eds), Elsevier Ltd, 67-81.

Noortman, H. J. (1984) *Goods distribution in urban areas. Goods distribution system in urban areas: report of the 61st round table on transport economics*. European Conference of Ministers of Transport, Paris.

Nuzzolo, A. and Comi, A. (2011). “A system of models for the assessment of city logistics policies”. In: *Proceedings of the 4th National Urban Freight Conference (NUF)*, Long Beach, CA, USA.

Nuzzolo, A., Crisalli, U. and Comi, A. (2006) “A modelling system for urban freight movements”. In: *Proceedings of the 11th International Conference of Hong Kong Society for Transportation Studies*, Hong Kong, China, 625-634.

Nuzzolo, A., Crisalli, U. and Comi, A. (2008) “Metropolitan freight distribution by railways”. In: *Innovations in City Logistics*, E. Taniguchi and R. G. Thompson (eds.), Nova Science Publishers, Hauppauge NY, U.S.A., 351-368.

Nuzzolo, A., Crisalli, U. and Comi, A. (2009) “A delivery approach modeling for urban freight restocking”. In: *Proceedings of the 12th International Conference on Travel Behaviour Research (IATBR),* Jaipur, India.

Nuzzolo, A., Crisalli, U. and Comi, A. (2011) “A Restocking Tour Model for the Estimation of O-D Freight Vehicle in Urban Areas”. In: *Procedia Social and Behavioral Sciences 20,* Elsevier Ltd, 140-149.

Nuzzolo, A., Crisalli, U. and Comi, A. (2012) “A trip chain model for simulating urban freight restocking”. In: *European Transport/Trasporti Europei 2012 (50),* ISTIEE, Trieste, Italy.

Nuzzolo, A., Crisalli, U., Comi, A. and Galuppi, S. (2010) “Demand models for the estimation of urban goods movements: an application to the city of Rome”. In: *Selected Proceedings of the 12th World Conference on Transportation Research-WCTR 2010,* Viegas, J. M. and Macario, R. (eds.), Lisbon, Portugal.

Ogden, K. W. (1992) *Urban Goods Movement*. Ashgate, Hants, England.

Oppenheim, N. (1994) *Urban Travel Demand Modeling*. John Wiley & Son, New York.

Quak, H.J. and de Koster, M.B.M. (2008) “Delivering Goods in Urban Areas: How to Deal with Urban Policy Restrictions and the Environment”. In: *Transportation Science 43,* Informs, 211-227.

Raothanachonkun, P., Sano, K., Wisetjindawat, W. and Matsumoto, S. (2007) “Truck trips origin destination using commodity based model combined with an empty trip model”. In: *Proceedings of the 86th Transportation Research Board Annual Meeting,* Washington DC.

Regan, A. C. and Garrido, R. A. (2001) “Modeling Freight Demand and Shipper Behaviour: State of the Art, Future Directions”. In: *Travel Behaviour Research: The Leading Edge*, D. Hensher (ed.), Pergamon, Amsterdam, 185-218.

Regue, R. and Bristow, A. L. (2012) “Exploring scenarios for the introduction of freight trams in Barcelona”. In: *Proceedings of 91st Annual Meeting of Transportation Research Board (TRB),* Washington D.C., U.S.A..

Rich, J., Holmbland, P.M. and Hansen, C.O. (2009) “A weighted logit freight mode-choice model”. In: *Transportation Research Part E 45,* Elsevier, 1006 – 1019.

Routhier, J.L. and Aubert, P.L. (1998) “FRETURB, un modèle de simulation des transports de marchandises en ville”. In: *Proceedings of the 8th World Conference on Transport Research*, Antwerp, Belgium.

Routhier, J.L. and Toilier, F., (2007) “FRETURB V3, a policy oriented software of modelling urban goods movement”. In: *Proceedings of the 11th World Conference on Transport Research*, Berkeley CA.

Russo, F. and Comi, A. (2004) “A modelling system to link end-consumers and distribution logistics”. In: *European Transport Journal, Special Issue on City Logistics n. 28*, Trieste, Italy, 6-19.

Russo, F. and Comi, A. (2010) “A modelling system to simulate goods movements at an urban scale”. In: *Transportation 37(6)*, DOI: 10.1007/s11116-010-9276-y, Springer Science+Business Media, LLC, 987 - 1009.

Russo, F. and Comi, A. (2011a) “Measures for sustainable freight transportation at urban scale: expected goals and tested results in Europe”. In: *Journal of Urban Planning and Development 137 (2)*, DOI: 10.1061/(ASCE)UP.1943-5444.0000052, American Society of Civil Engineers (ASCE), 142-152.

Russo, F. and Comi, A. (2011b) “A Model System For The Ex-Ante Assessment Of City Logistics Measures”. In: Research in *Transportation Economics 31 (1)*, DOI: 10.1016/j.retrec.2010.11.011, Elsevier Ltd, 81-87.

Russo, F., Comi, A. and Polimeni, A. (2008) “Urban freight transport and logistics: Retailer’s choices”. In: *Innovations in City Logistics*, E. Taniguchi and R. G. Thompson (eds.), Nova Science Publishers, Hauppauge NY, U.S.A., 401-414.

Russo, F., Vitetta, A. and Polimeni, A. (2010) “From single path to vehicle routing: the retailer delivery approach”. In: *Procedia - Social and Behavioral Sciences 2(3)*, E. Taniguchi and R. G. Thompson (eds.), DOI: 10.1016/j.sbspro.2010.04.046 Elsevier Ltd, 6378-6386.

Schoemaker, J. (2006) *BESTUFS II – Improving attractiveness of cities with city freight solutions*. BESTUFS Consortium, www.bestufs.net..

Sonntag, H. (1985) “A Computer Model of Urban Commercial Traffic”. In: *Transport, Policy and Decision Making. 3 (2)*, 171-180.

Spielberg, F. and Smith, S. A. (1981) “Service and supply trips at federal institutions in Washington, DC area”. In: *Transportation Research Record 834, 15-20*

Stathopoulos, A., Valeri, E., Marcucci, E., Gatta, V., Nuzzolo, A. and Comi, A. (2011) “Urban freight policy innovation for Rome’s LTZ: A stakeholder perspective”. In: *City distribution and urban freight transport: multiple perspectives*, Melo, S. and Macharis, C. (eds.), Edward Elgar Publishing, Cheltenham UK, 75-100.

Stefan, K.J., J.D.P. McMillan and J.D. Hunt (2005) “Urban Commercial Vehicle Movement Model for Calgary, Alberta, Canada”. In: *Transportation Research Record 1921*, 1-10.

Taniguchi, E. and Thompson, R. G. (2010) *Procedia - Social and Behavioral Sciences 2(3) - The Sixth International Conference on City Logistics*, Elsevier Ltd.

Taniguchi, E., Thompson, R. G., Yamada, T. and van Duin, R. (2001) *City Logistics – Network Modelling and Intelligent Transport Systems*. Pergamon.

Thorson, E. (2005) *The Integrative Freight Market Simulation: An Application of Experimental Economics and algorithmic Solutions*. Civil and Environmental Engineering. Troy, NY, Rensselaer Polytechnic Institute. Ph.D. dissertation.

Wang, Q. and Holguin-Veras, J. (2008) “An investigation on the attributes determining trip chaining behavior in hybrid micro-simulation urban freight models”. In: *Proceedings of the 87th Transportation Research Board Annual Meeting*, Washington DC.

Wang, Q. and Holguin-Veras, J. (2009) “Tour-based entropy maximization formulations of urban freight demand”. In: *Proceedings of the 88th Transportation Research Board Annual Meeting,* Washington DC.

Wang, Q. and Hu, J. (2012) “Behavioral Analysis of Commercial Vehicle Mode Choice Decisions in Urban Areas” In: *Proceedings of 91st Annual Meeting of Transportation Research Board (TRB)*, Washington D.C., U.S.A..

Wisetjindawat, W., Sano, K. and Matsumoto, S. (2005) “Supply chain simulation for modeling the interactions in freight movement”. In: *Journal of the Eastern Asia Society for Transportation Studies (6)*, 2991 - 3004.